Design Development of the General Aviation eHUD Flight Display

For the
Quarterly Review of the NASA/FAA Joint University Program for Air Transportation Research

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Project Sponsor: Joint University Program

Introduction

- General Aviation Instrumentation has undergone little change in the past 50 years.
- In 1999, 73% of the fatal accidents were caused by night Instrument Meteorological Conditions (IMC).
- IFR traffic is expected to increase by 2.5 percent per year over the next decade.
- Increase in IFR traffic might lead to a possible increase in GA accidents.

Overview

- Motivation Behind eHUD
- Pseudo-Attitude Determination
- Current eHUD System Overview
- Flight Tests
- Data Comparison, 5 Hz vs. 20 Hz
- Pseudo-Attitude Demonstration
- Future Work

Motivation Behind eHUD

- Provide Visual Cues in IMC.
- Increase Situational Awareness in IMC.
- Reduce pilot training and recurrency requirements for flight in IMC.
- Keep the pilot looking out the window at the same time they are flying the instrument approach.
- Cost effective Head-Up Display.

Attitude

The Merriam-Webster Dictionary defines *attitude* as the position of an aircraft or spacecraft determined by the relationship between its axes and a reference datum.

Traditional Attitude:

- Three GPS Receivers, three Antennas.
- Expensive and Computationally Intensive.

Pseudo-Attitude (*Velocity Vector Based Attitude*):

- Observable from a single GPS antenna.
- Cost effective to purchase and install.

Pseudo-Attitude Determination

(*Velocity Vector Based Attitude Determination*)

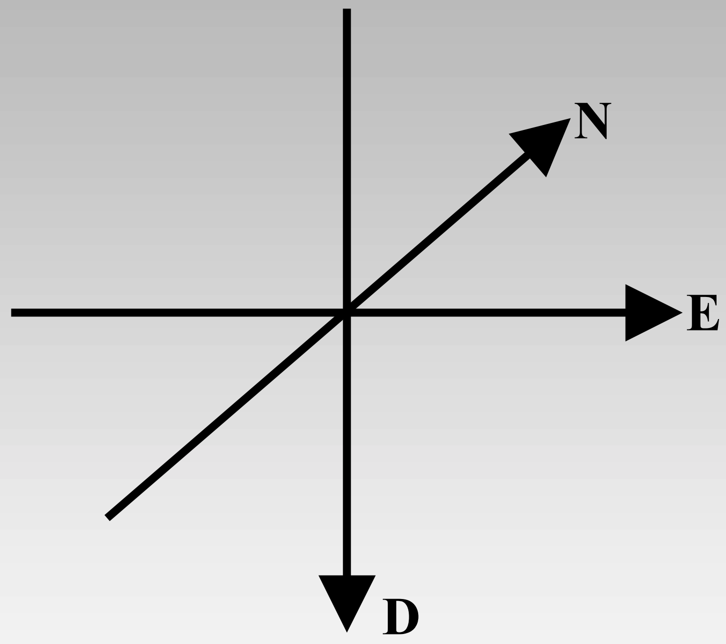
Developed at the Massachusetts Institute of Technology by:

- Dr. Richard P. Kornfeld
- Dr. R. John Hansman
- Dr. John J. Deyst

The information on the following slides, regarding Velocity Based Attitude, was taken from "***The Impact of GPS Velocity Based Flight Control on Flight Instrumentation Architecture***" Report No. ICAT-99-5, June 1999.

Reference Frame

(*North, East and the Local Vertical Down.*)



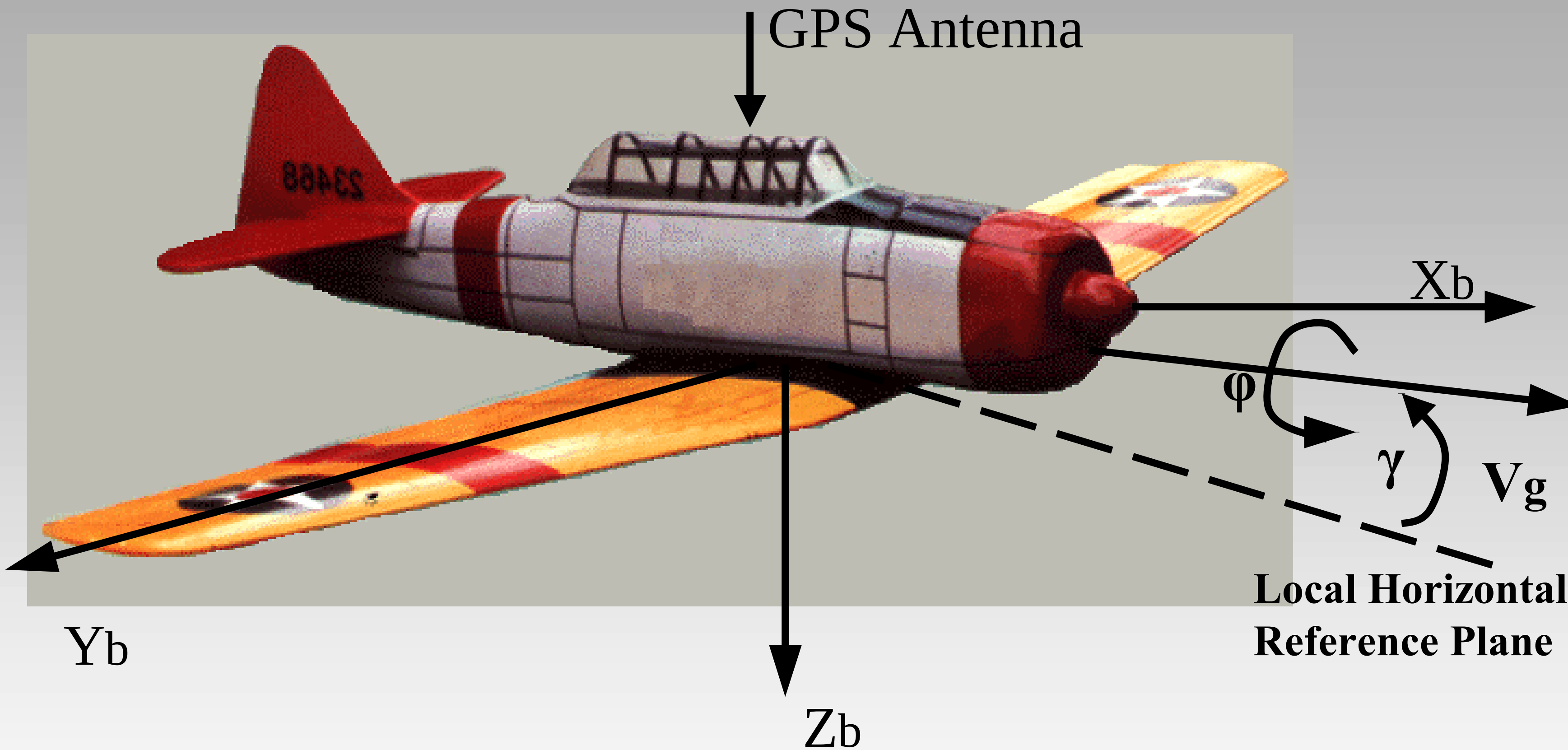
$$\mathbf{N} \times \mathbf{E} = \mathbf{D}$$

Velocity Vector

$$\mathbf{V_g = (V_{gN}, V_{gE}, V_{gD})}$$

FNED: Earth-Fixed locally level coordinate system.

Pseudo-Attitude



Flight Path Angle : γ

Pseudo-Roll Angle : φ

F**B:** Body-fixed orthogonal axes set which has its origin at the aircraft center of gravity.

Modifications to the eHUD

Phase 1:

- Updated GPS Receiver to a Novatel OEM4 with 20 Hz position and velocity data.
- Collected 35 minutes of flight data with the new receiver.

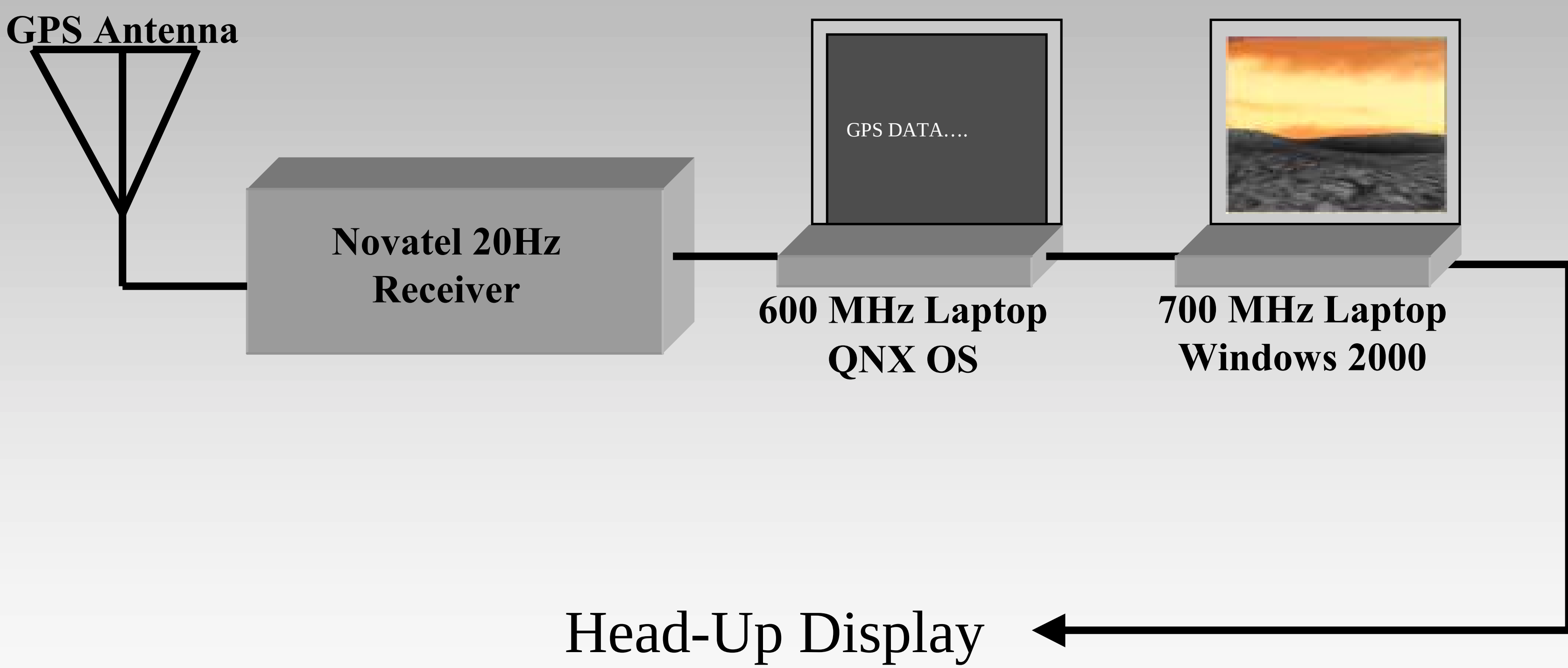
Phase 2:

- Velocity Vector Attitude Determination algorithm was rewritten.

Phase 3:

- An alternative display processor was developed.

Current eHUD Configuration



Novatel GPS Receiver

- 20 Hz Velocity Data
- 20 Hz Position Data
- RS-232 serial port

GPS Receiver provides position and velocity information to the real-time processor for ***Pseudo-Attitude Determination.***

Position and Velocity Strings

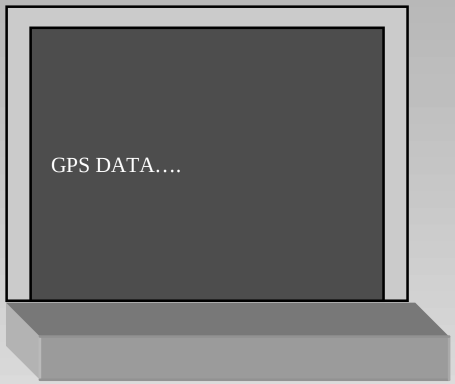
Position (BESTPOSA)

- GPS Sec into the Week.
- Latitude
- Longitude
- Height

Velocity (BESTVELA)

- GPS Sec into the Week.
- Horizontal Speed (m/s)
- Ground Track (degrees)
- Vertical Speed (m/s)

Real Time Processor



Gateway 600 MHz Laptop

- QNX Real-Time OS
- PCMCIA Card
- Serial/Parallel Ports

The real-time processor transforms the Velocity Data into the ***Velocity Vector***, $\boldsymbol{V_g = (V_{gN}, V_{gE}, V_{gD})}$. This is used to calculate the ***Flight Path Angle*** and the ***Pseudo-Roll***, which are sent to the display processor along with the position information.

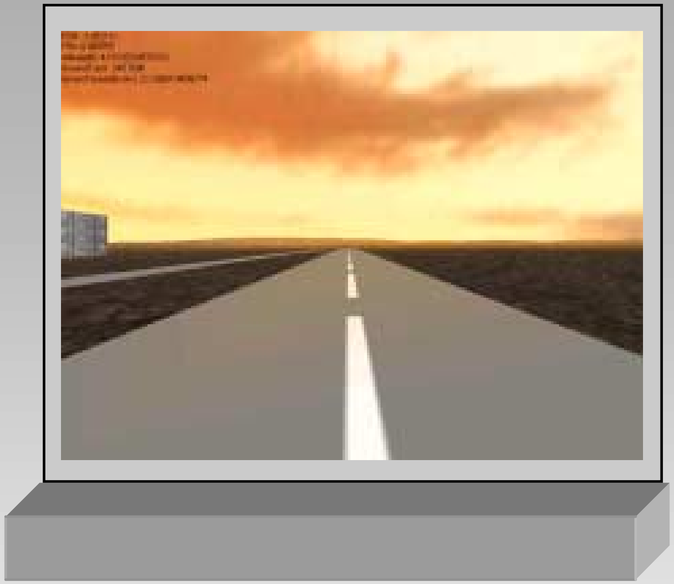
Processing GPS Data

- Input Buffer Read When Serial Com Interrupt is Received
- Incoming String is Parsed According to Type
- If Incoming Time-stamp Correlates to Previous GPS String’s Time-stamp Then Velocity Vector is Processed
- Flight Data is Sent to the Display Processor

Flight Data Parameters

1. Time-stamp (GPS Seconds into the Week)
2. Latitude
3. Longitude
4. Height (meters)
5. Ground Speed (m/s)
6. Ground Track (degrees)
7. Flight Path Angle (degrees)
8. Pseudo-Roll (degrees)

Display Processor



- 700 MHz Laptop Running Windows 2000
- Display Written in Visual Basic
- Graphics Produced Using Revolution 3D
- Three-Dimensional representation of the outside world

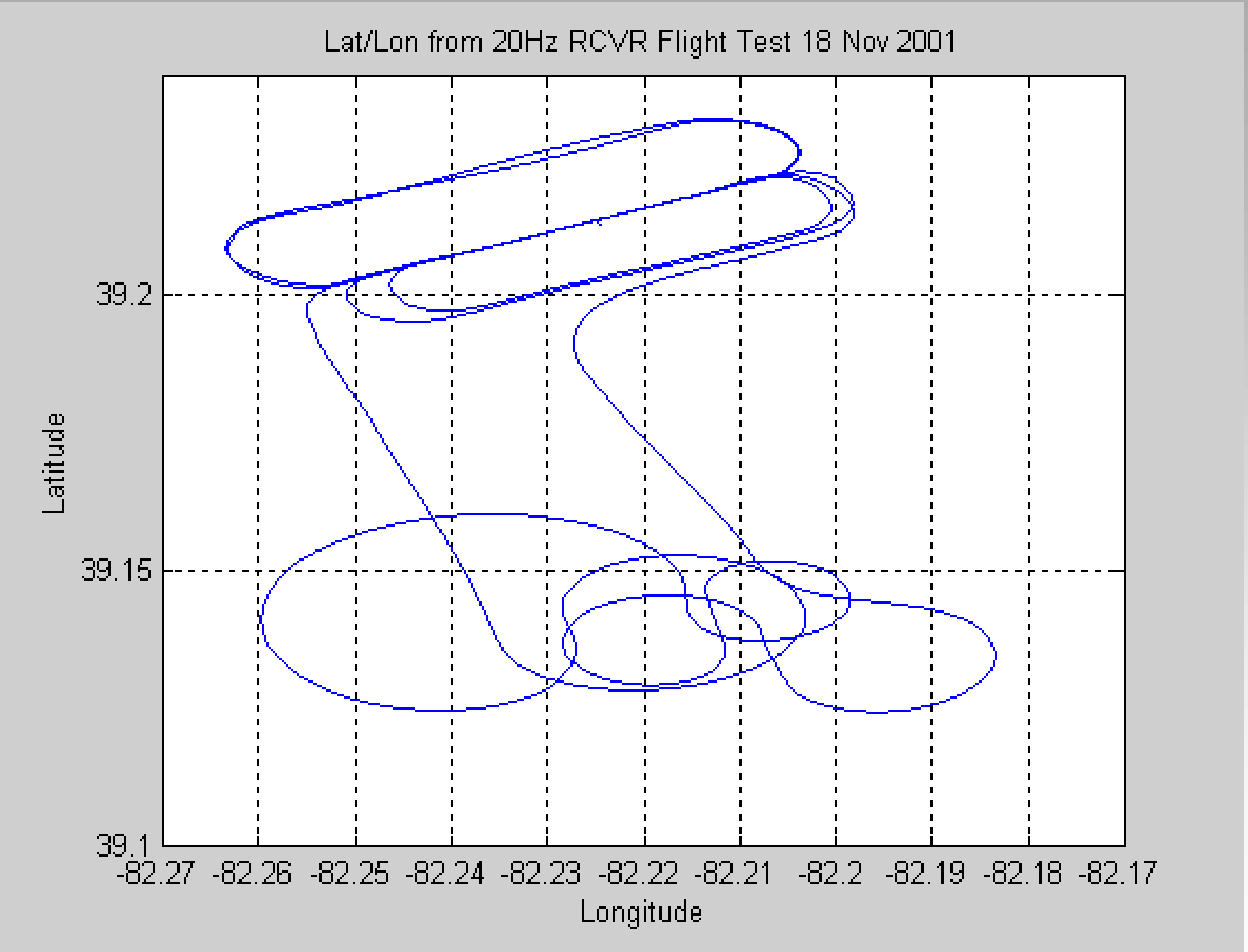
Data Collection Flight Test

- Flight Test Conducted 18 Nov, 2001
- Consisted of Four Touch-and-Go Landings on UNI Runway 25, Followed by Banking Maneuvers
- GPS Antenna Mounted Approximately Above Aircraft Center of Gravity
- BESTPOSA and BESTVELA GPS Strings Collected at 20Hz

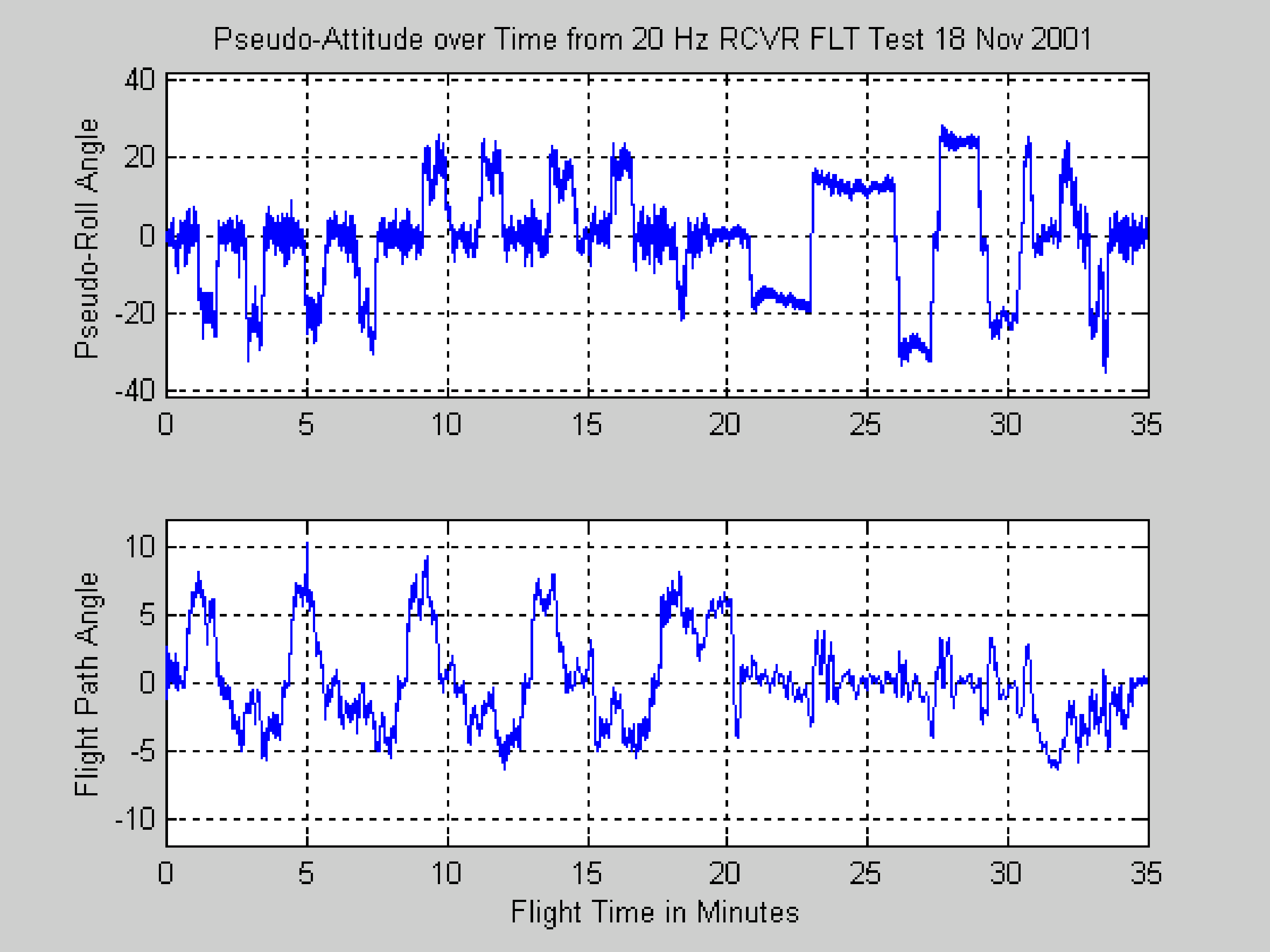
Real-time Flight Test

- Conducted on 2 Jan 2002.
- OEM-4 GPS Receiver Connected to 600 MHz Laptop.
- GPS Seconds, Pseudo-Roll, and Flight Path Angle Displayed on Screen in Text Format at 5 Hz.
- Velocity Vector Processed Real-time.

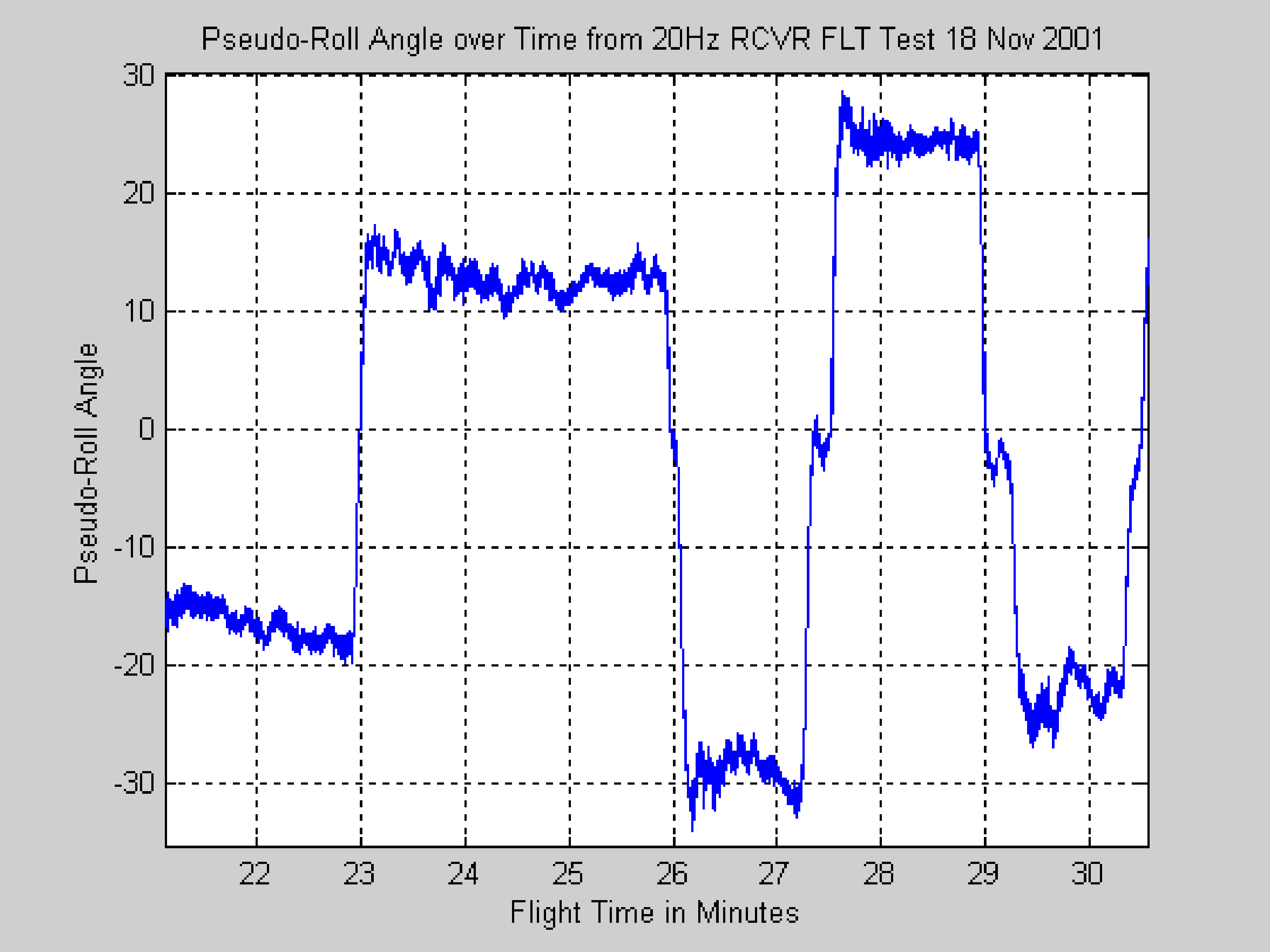
Data Collection Flight Path



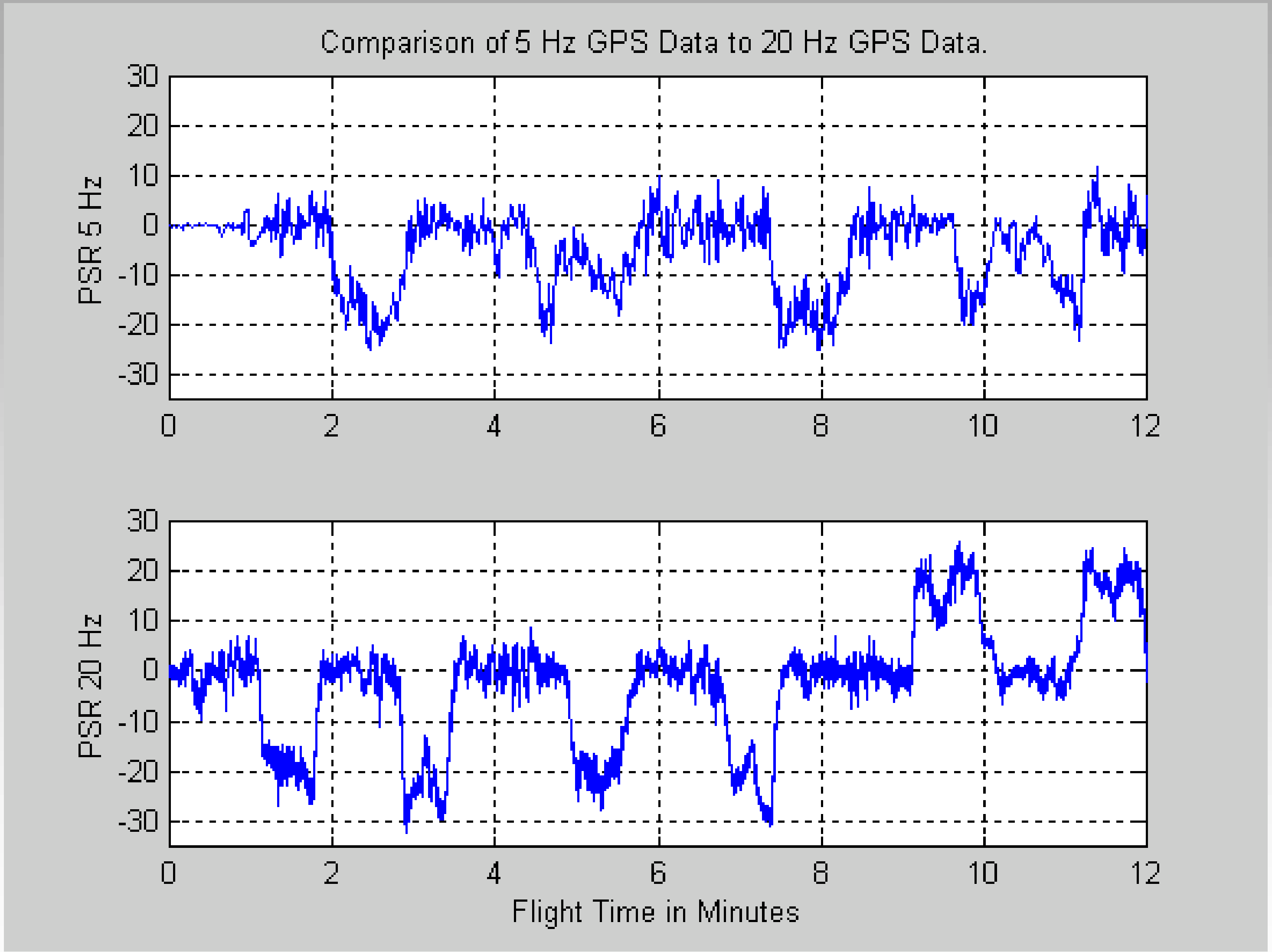
Pseudo-Attitude



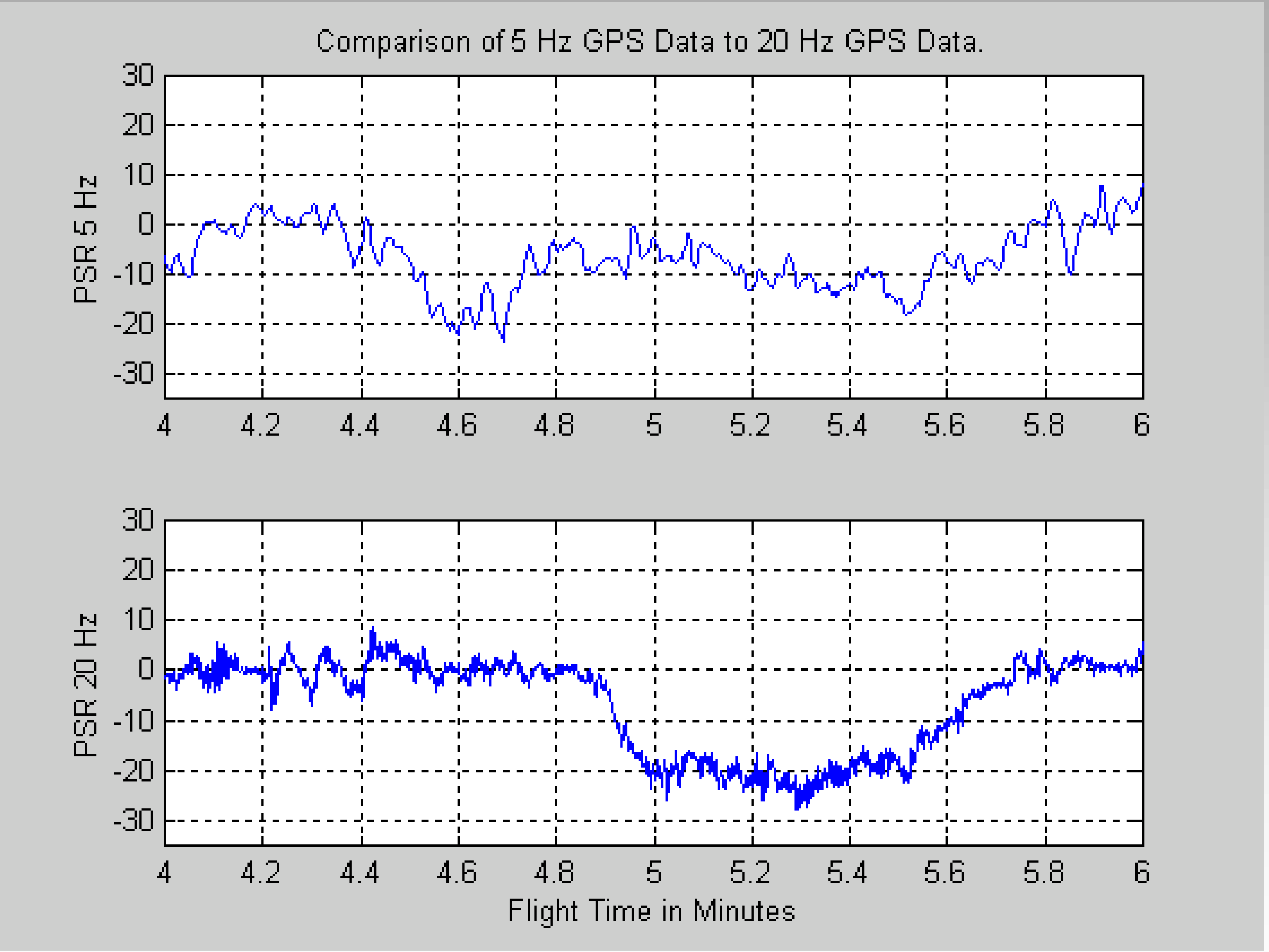
Closer Look at the Pseudo-Roll



GPS Data, 5 Hz vs. 20 Hz



Resolution Comparison



Flight Test Demonstration

Concerns

- Vertical Error Inherent With GPS
- Augmenting System With Accurate Height Information
- Display Perspective
- The Many Human Factors Associated With Head-Up Displays

Future Work

- Keep the development of the eHUD completely in-house. Use tools that will allow us to personally develop graphical displays, projection, etc. and not depend on others to make modifications.
- Augment System with reliable height information.
- Update the Pilot Display to a modern implementation of a Head-Up Display.

Contact Information

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References

- Kornfeld, R.P., Hansman, R.J., Deyst, J.J., *The Impact of GPS Velocity Based Flight Control on Flight Instrumentation Architecture*. MIT International Center for Air Transportation, Cambridge, MA. Report No. ICAT-99-5, June 1999.
- Eric Theunissen. Integrated Design of Man-Machine Interface for 4-D Navigation (1997) Delft University Press, Mekelweg 4 2628 CD Delft, The Eric's Web page: www.tunnel-in-the-sky.tudelft.nl.